

Topic: Hybrid Semiconductor Nanostructures As Unique Capabilities in the direct detection of proteins, viruses, and DNA

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Nano approach to fighting cancer is exploding. Devices based on field-effect transistors (FETs) are one of emerging fields for sensing technology. Several other research terms have made similar progress in electrically detecting cancer specific markers using new types of nanodevices. Lieber and colleagues doped charge-carrying silicon nanowires with monoclonal antibodies specific for the cancer proteins. When the proteins linked up with the antibodies, the electrical charges of the proteins changed the conductance of the silicon wires. This change signaled the presence and concentration of cancer markers. Hence, the electrical signal transduction plays an important role on EFTs devices for the direct detection of biological and chemical species. In addition to silicon nanowires, today nanostructured semiconducting oxides, such as SnO_2 , ZnO_2 , and V_2O_5 , have attracted extensive interest because of their distinctive electronic and/or optical properties. In particular, individual nanowires or nanotubes have been fabricated recently on field-effect transistor devices that provide a very promising technology for chemical and biological sensors. However, the electrical signal transduction for semiconductor oxides in general take place at high temperature (above at 200°C), at which temperature environment will damage biomolecules.

To enhance the room-temperature sensor transduction of chemical/biological binding evens into electronic/digital signals at room temperature, in the first year project (2006) we proposed an entirely new ideal to synthesize organic-inorganic hybrid synergistic semiconductors. We suggested that the redox organic radical molecules may be trapped into the crystalline oxide to become a new hybrid-semiconductor that is thought to enrich electronic transport through the surface of the oxides. Such an attractive organic-assisted semiconductor might lead to versatile system not only for redox catalysis, battery applications, but also as chemical and biological sensors. To day some exciting data for VO_x fibres are shown as the follows as:

- (1) We have successfully synthesized a new hybrid semiconductor fiber material, a redox bipyridinium system trapped in fibers of vanadium oxide, under hydrothermal conditions. The as-synthesized oxide fibers are pure, structurally uniform, and single crystalline on the basis of SEM, HRTEM, and XRD, as shown in Figure 1. On the analysis of morphologies, it was found that they have a rectanglelike cross section with typical thickness of 60 to 300 nm, width-to-thickness ratios of 5 to 10, and lengths of up to a few millimeters.

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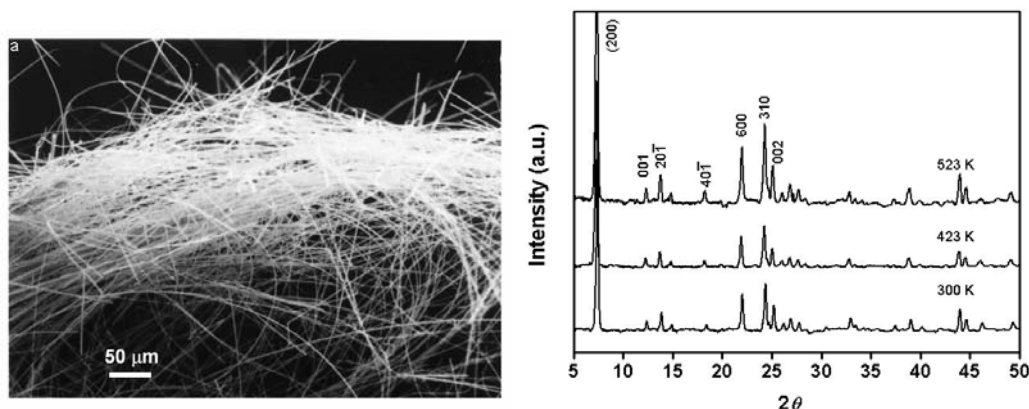


Figure 1 Structural characterizations for $MV^{+}@VO_x$ fibers. **(A)** Low-resolution SEM morphology of the as-synthesized $MV^{+}@VO_x$. **(B)** *In situ* powder X-ray diffraction patterns for the $MV^{+}@VO_x$ fibers with synchrotron radiation, $\lambda = 1.32633 \text{ \AA}$, at temperature of 303, 423, and 523 K.

- (2) Furthermore, electronic conductivity of single fibre of VO_x was conducted by four probe method shown in Figure 2. It reveals excellent conductivity (exceeding 3 Scm^{-1}) with low thermal activation energy (0.04 eV), indicating that The role of bipyridinium molecules in fiber oxides enriches the hopping between V^{5+} and V^{4+} redial centers and thus promotes the excellent electronic properties.

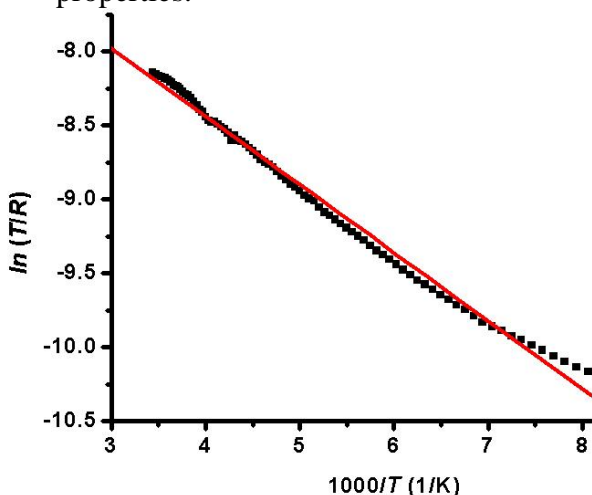


Figure 2 Temperature dependence of individual fiber resistance. $\ln(T/R)$ versus reciprocal temperature in the range of 75 – 300 K.

- (3) Finally, this finding opens up tremendous possibilities for exploiting the highly sensitive, real-time electrically based sensor for chemical and biological species at room temperature, along with the useful conductivity. Our preliminary test data show that the hybrid fibers have strong interaction with CO molecules at room temperature, thus increasing the electronic conductivity as linear function of CO concentration that extrapolated a lower detection limit of about 70 ppm for CO in air, as shown in Figure 3.

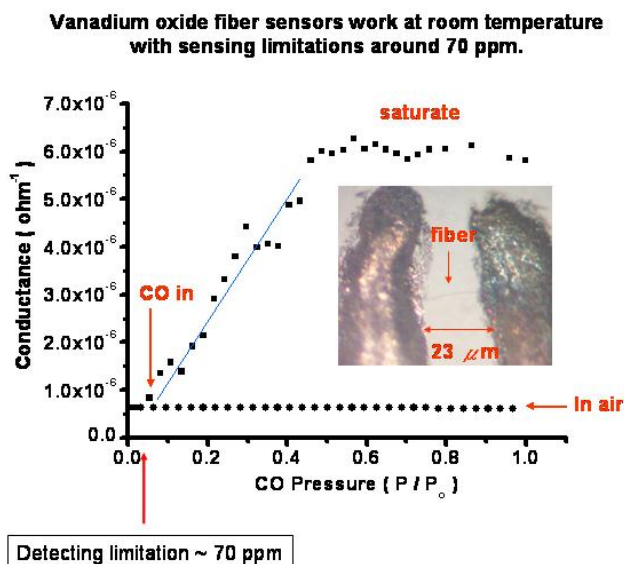


Figure 3. CO sensing for fibres of VOx.

Moreover, by using single-wired fabrication technology (see Figure 4), it was found that the resistance of the organic-radical VOx was gradually increasing upon N₂ gas, but decreasing in O₂ gas (as shown in Figure 5). Further work was in progressing to understand the gas sensing effect.

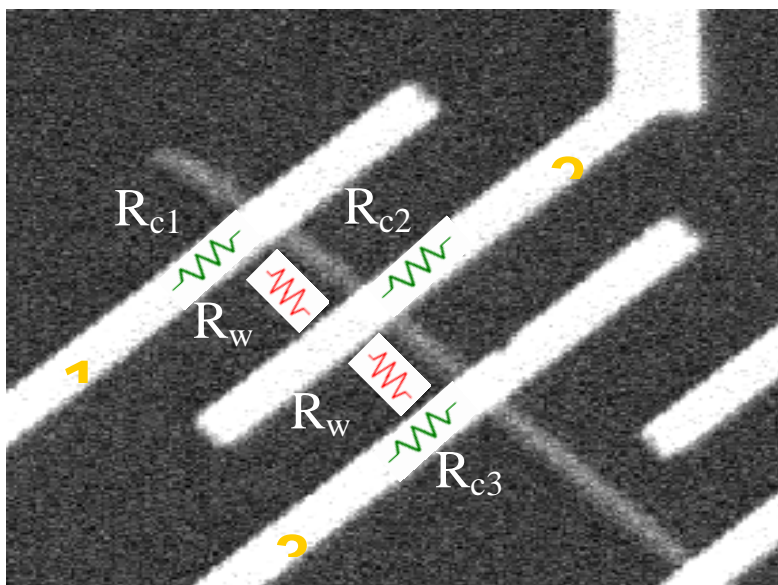


Figure 4. Fabrication of a single-wire of organic-containing VOx.

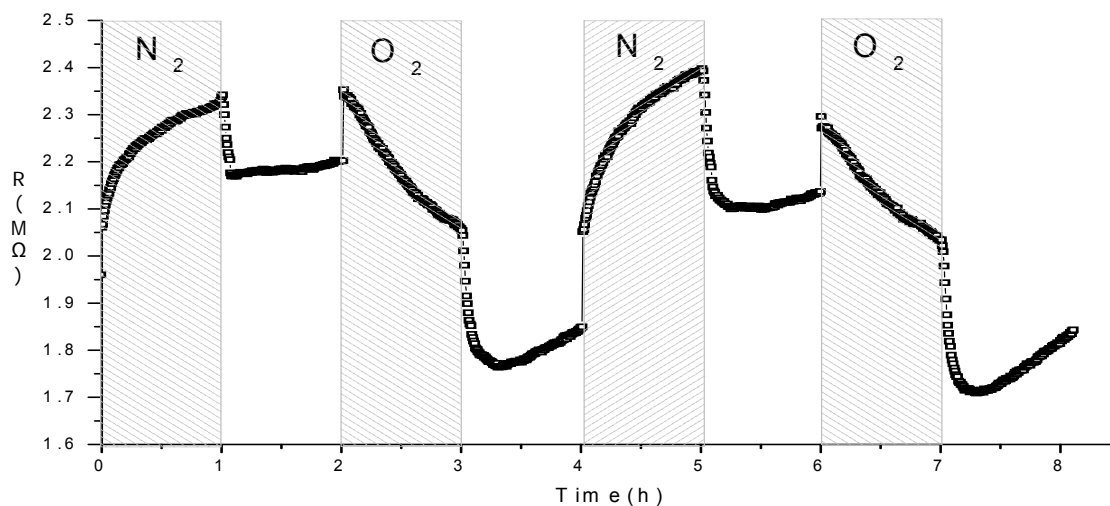


Figure 5. Resistance response of N_2 and O_2 gas for a single-wire organic-containing VO_x .

Overall, in the first year, we have successfully prepared the organic-containing VO_x fibres whose resistance has significant sensitivity on gas molecules such as CO, N_2 , and O_2 by using single-wired fabrication. Further works, in situ IR and Raman spectra were used to realize the surface interaction between the wires and gas molecules.

Related publications:

1. K. J. Lin et al., Radical-Viologen Hopping electrical bistability in Mixed-Valence Vanadium Oxide for Nonvolatile Memory Application. In manuscript.
2. K. J. Lin et al., Radical Spin-ordering in Mixed-Valence Vanadium Oxides that Exhibited Intrinsic Stepwise Ferromagnetic Semiconductor at Room-Temperature. In manuscript.
3. Ko, Wen-Yin; Chen, Wei-Hung; Tzeng, Shien-Der; Gwo, Shangir; Lin, Kuan-Jiuh*; Synthesis of Pyramidal Copper Nanoparticles on Gold Substrate. *CHEMISTRY OF MATERIALS* 18 (26): 6097-6099 DEC 26 2006 .
4. Wen-Yin Ko, Wei-Hung Chen, and Kuan-Jiuh Lin*, Highly Electrocatalytic Reduction of Nitrite Ions on a Copper Nanoparticles Thin Film. Submitted to *Langmuir*.